



The Next Generation Space Telescope

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NGST MISSION OVERVIEW

NGST Study Team

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SEARCHING FOR THE ORIGIN of the universe is very much like archeology. Astronomers, like archeologists, must peel away the strata of time to find clues. Over the past few decades, astronomers have made great progress doing just that — peering farther and farther back in space and time to study objects that existed when our universe was still very young.

Astronomers have uncovered tantalizing clues in images taken by the Hubble Space Telescope (HST). In one image (Figs. 1 and 2), they found a myriad of galaxies that formed perhaps 5 billion years after the Big Bang. Surprisingly, the fledgling galaxies seem very well-developed and exhibit many of the features of current galaxies. From this, astronomers have deduced that the galaxies formed much earlier — perhaps only a few billion years after the cataclysmic explosion that gave birth to the universe.

Astronomers also have uncovered clues in data gathered by the Cosmic Background Explorer (COBE) (Fig. 3).

FIG. 1. The Hubble Deep Field. Several hundred never-before-seen galaxies are visible in this “deepest-ever” view of the universe, made with NASA’s Hubble Space Telescope. Besides the classical spiral and elliptical shaped galaxies, there is a bewildering variety of other galaxy shapes and colors that are important clues to understanding the evolution of the universe.

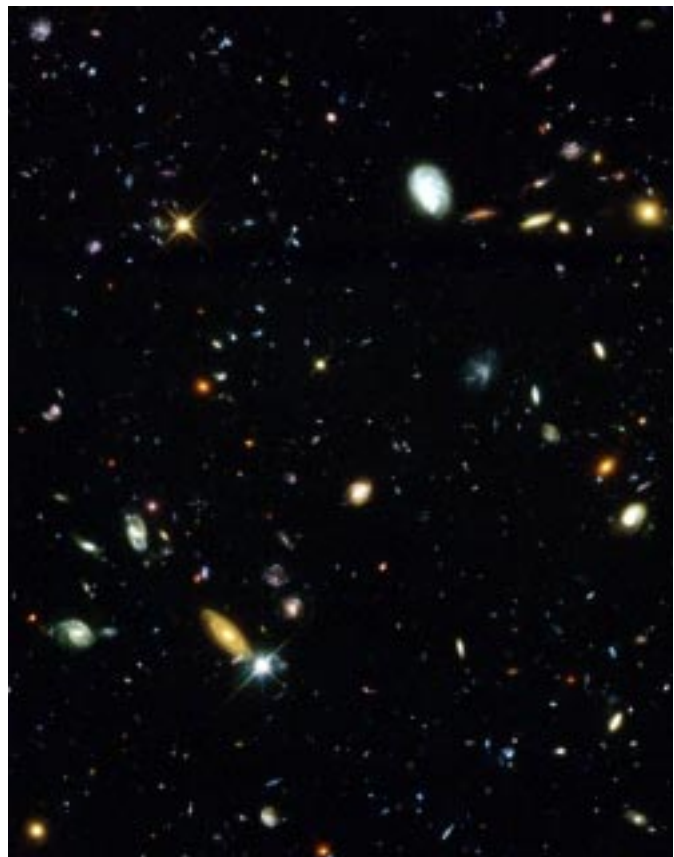




FIG 2. Hubble Deep Field (detail). This detail shows distant spirals and spherical galaxies as well as blue, disturbed galaxies that are presumably large star forming regions, perhaps within a larger undetected host galaxy.

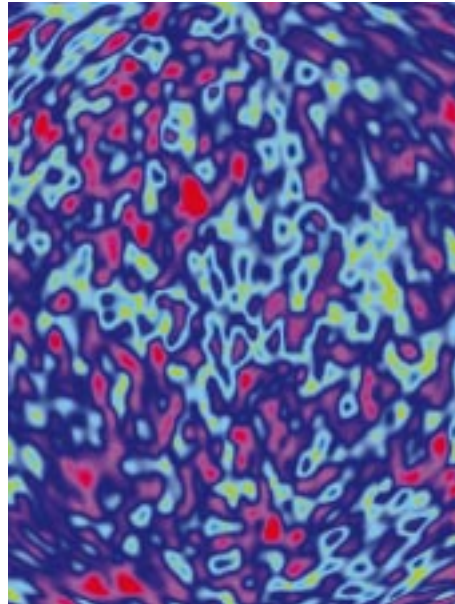


FIG 3. COBE reveals the Beginning of Structure. This Cosmic Background Explorer (COBE) false-color map of the sky shows tiny differences in the density of matter in the universe soon after the Big Bang. High-density regions (blue) are believed to have evolved into the largest scale structure seen in the universe today.

The explorer-class observatory detected the seeds of galaxies and other large-scale structures that began to evolve just 300,000 years after the Big Bang. How did these seeds condense into the stars and galaxies observed by Hubble? This period of time might be called the “dark zone” — a gap in the history of our universe that holds the secrets of its evolution.

The Answer

To see the first generations of stars, the science community believes it will need a successor to Hubble. Even with new instruments, Hubble’s observations are limited to “adolescent” objects. The younger objects, which are receding from us at an even faster rate, are redshifted into the near infrared (past 2 microns) where Hubble loses sensitivity. Known as the Next Generation Space Telescope (NGST), the observatory will be sensitive to infrared radiation and, with its large light-gathering mirror and superb resolution, capable of detecting faint signals from the first billion years — the period when galaxies formed.

For such observations, the new telescope will be chilled to the low temperatures of outer space and placed in an orbit beyond the Moon. The location and low temperatures make the observatory thousands of times more sensitive than Earth-bound telescopes, and enables astronomers to see how and when the first generations of stars appeared and how quickly those stars manufactured the heavy elements that eventually became the material for worlds like Earth.

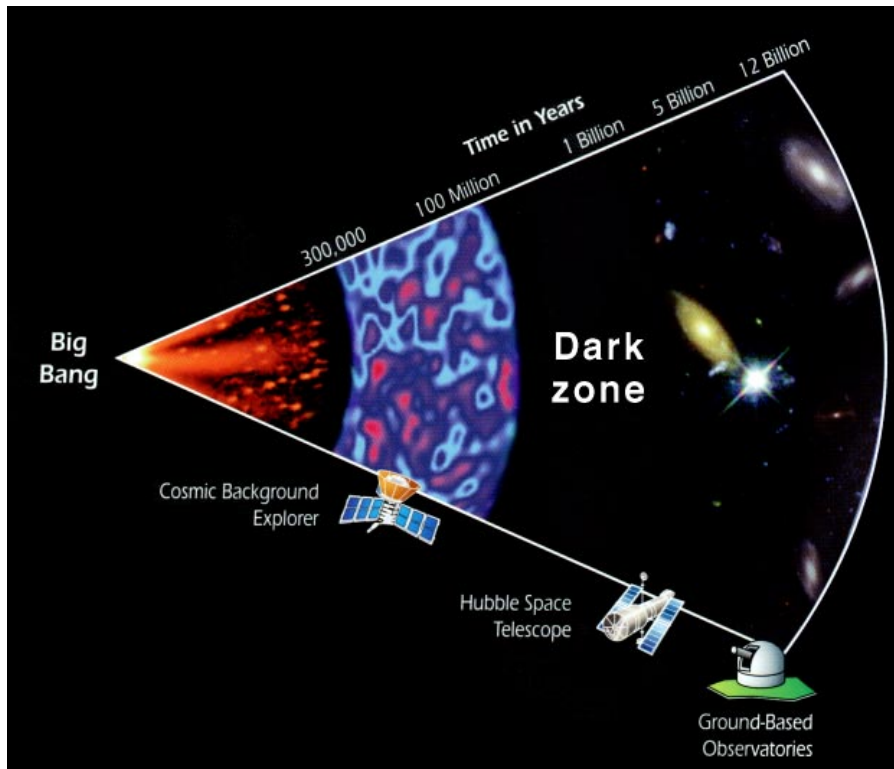
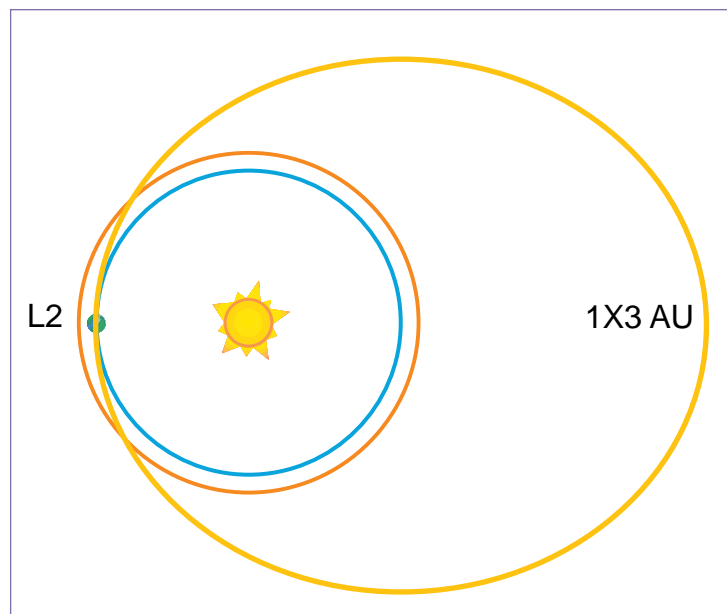


FIG 4. Visiting a Time When Galaxies Were Young. NGST will observe the "dark zone," a period when primordial seeds began to evolve into the galaxies and stars we see today.

FIG 5. NGST Orbit. To enhance its performance, scientists hope to place the observatory as far from the Earth-Moon system as possible to reduce stray light and to maintain the telescope's relatively cool temperature. Two orbits being considered are the second Lagrange point (L2) and a 1X3 AU solar orbit.



With such a capability, astronomers will finally lift the veil that now obscures the dark zone of the universe's first billion years.

HST & Beyond Report

Today, astronomers have at their disposal a variety of ground- and space-borne telescopes and instruments, operating at a wide range of wavelengths. Given the variety, and the intense competition for funding, the science community is mindful that a solid scientific case is needed to support a follow-on mission to the enormously successful Hubble Space Telescope.

In its report, "HST and Beyond," the blue ribbon committee appointed by the Association of Universities for Research in Astronomy (AURA) recommended such a follow-on mission. The report urged the development of a general-purpose, near-infrared observatory equipped with a primary mirror larger than 4 meters. Able to maintain a cool temperature of 70 K or lower, the observatory would be up to 1,000 times more sensitive than any existing or planned facility in the 1-5 micron region. To further enhance its performance, the report recommended that the observatory be placed as far from the Earth-Moon system as possible to reduce stray light and to maintain the telescope's relatively cool temperature.

With such capability, the panel concluded that future generations of astronomers could learn in detail how galaxies formed. They could determine the shape of the very early universe by measuring standard candles such as supernovae. They could trace the chemical evolution of galaxies as stars released their material back into space. And they could study nearby stars and star-forming regions for signs of planetary systems such as our own. This facility would be a major step toward answering one of the most profound questions known to humankind: Are we alone in the universe?

Feasibility Studies

For the science community, the issue of whether to pursue a follow-on mission is not one of need, but rather one of technical and financial feasibility. The question becomes: Can NASA build a technically challenging next-generation space telescope in an era of reduced funding?

With support from NASA Headquarters, the Goddard Space Flight Center and the Space Telescope Science Institute led a team made up of other NASA field centers and engineering firms to study whether NASA could realize that vision. To make sure it gathered the best ideas that academia and industry could offer, the agency funded two independent studies by consortia led by Lockheed Martin and TRW.

All three teams found that NASA could launch NGST by 2005. They also confirmed that because of advanced technology and the requirement that the observatory have one-fourth the mass of Hubble, the agency would be able to build NGST for significantly less than the \$2 billion (1990 dollars) it had invested in Hubble. Each of the studies assumed, however, that NASA would receive at least \$175 million (1996 dollars) for mission definition and technology development and another \$500 million for construction.

The Concepts

Although the study teams believe NGST is feasible with the development of certain technologies, they also understand that the program faces many challenges. As the feasibility studies point out, NGST will require a very different design from any observatory flown before. NGST will fly a significantly larger mirror, even though the observatory itself will be much less massive — especially compared with the Hubble Space Telescope's school bus-sized dimensions.

The study teams based their analyses on the following criteria: First, the telescope should operate far from Earth to maintain its cool temperature. Second, it should be lightweight and compact so that a mid-sized launch vehicle, such as the Atlas IIAS, could carry it into space. (The Atlas IIAS, for example, can for about \$100 million transport 2800 kg to the Lagrange point L2 — one of the orbits under consideration.) And third, the telescope's mirror should be adjustable in flight to correct for deployment misalignments and thermal effects.

NASA and its industry and academic partners studied three approaches:

- Deployable 8 m segmented primary mirror telescope and erectable sunshield, deployed at L2 (TRW) (Fig. 6a).
- Monolithic 6 m thin shell primary mirror telescope and fixed sunshade, in an interplanetary orbit beyond that of Mars (Lockheed Martin) (Fig. 6b).
- Deployable 8 m segmented primary mirror telescope and inflatable sunshield, deployed at L2 (GSFC) (Fig. 6c).

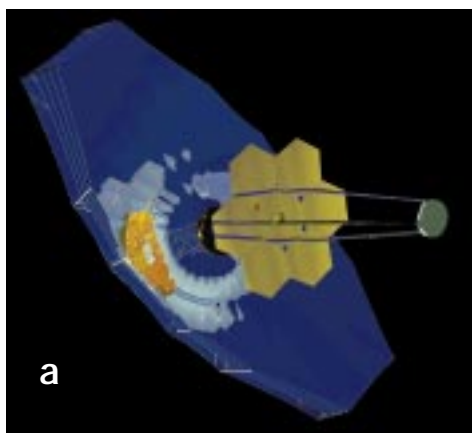
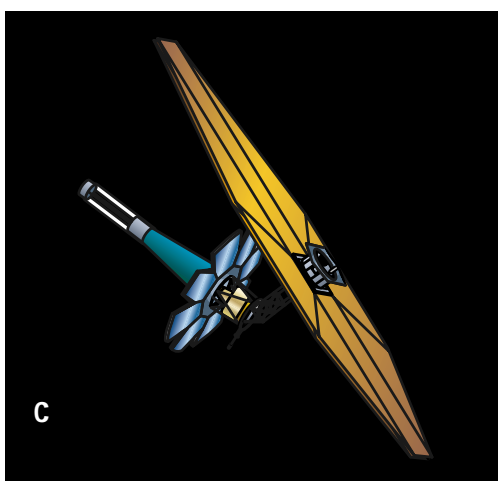
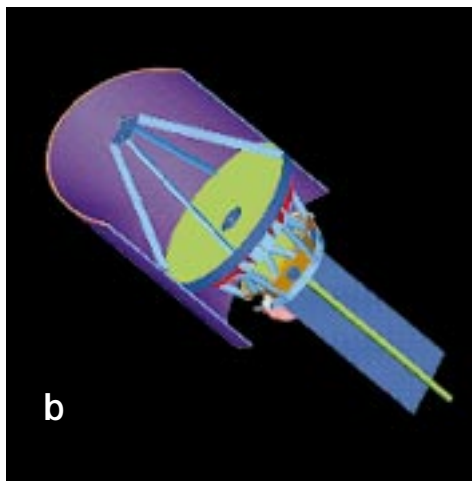


FIG 6. (a) TRW model; (b) Lockheed Martin model; (c) Goddard model.



All three concepts share certain design features, including adjustable thin mirrors, deep space orbits, fast-steering mirrors for fine guidance, infrequent contact with the ground and a mass of about 2800 kg. They differ in the areas of mirror construction, materials and deployment, detector types, sunshield types, vibration control and launch vehicles.

Technology Readiness

The most important and difficult part of the mission is designing and building the primary mirror (Fig. 7). While the mirror would be the largest ever flown on a space-borne observatory,

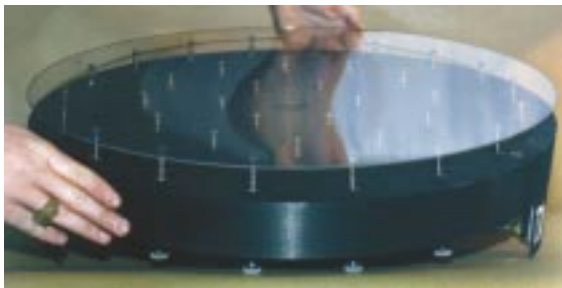


FIG. 7. NGST Mirror. This prototype is the first ultralightweight mirror made using GMARS technology-Glass Membrane with Active Rigid Support. The 0.5 m diameter mirror combines a 2 mm thick Zerodur membrane and 36 piezo-driven screw actuators for on-orbit wavefront control with a carbon fiber support for a total mass of 5 kg. (Lockheed, University of Arizona)

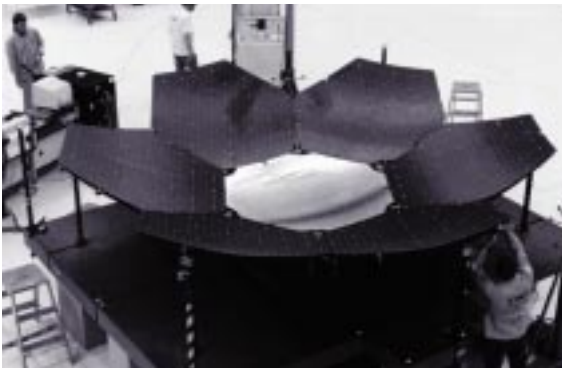


FIG. 8. Precision Deployable Structure Prototype. A 4.5 m diameter reflector constructed for the TRW High Accuracy Reflector Development program (HARD). Composed of seven, 2 m hexagonal panels, the deployed reflector has been successfully tested for use at 60 GHz. It has been qualified for missions launched on the Shuttle or a Titan IV. (TRW)

it would have to remain relatively lightweight to meet the mass requirements. Despite these challenges, the study teams studied several approaches that would work. In short, the main conceptual breakthroughs needed to carry out NGST are available today.

The University of Arizona, which was part of the Lockheed Martin team that studied the 6 m monolithic mirror, has already demonstrated a sample mirror that meets NGST's weight and accuracy requirements. The necessary sensor and computer algorithms to control such a mirror are already used at ground-based observatories, as well.

It also appears possible to deploy a segmented primary mirror and adjust it to the correct figure after launch — the approach suggested by the GSFC and TRW teams. With this design, NASA could build an 8 m mirror which would fold down to fit inside the Atlas IAS 4 m launch shroud. Making the concept even more attractive is the fact that TRW built a space-qualified deployment mechanism around 1987 for a 60 GHz antenna with a 4.6 m aperture (see Fig. 8).

The other advances needed for the NGST are within reach, too. Improved infrared detectors are as important as improved telescope efficiency and collecting area. NASA's SIRTf mission has demonstrated detectors that are close to meeting the NGST sensitivity requirements.

Further Study Required

Further study is required before NASA and the scientific community can recommend a particular approach. The program is still in the early stages. In addition to unresolved technology questions, the question of how to transport the observatory to orbit remains unresolved. Mission planners need to know the cost and shroud sizes of launch vehicles that will be available less than a decade from now. The availability of a large, yet affordable rocket might make a non-deployable telescope more attractive. However, scientists and engineers also could argue that a deployable telescope would give mission planners experience building the ultimate system — one that could image an Earth-sized planet around another star.

In other words, NASA's strategic plan is as significant a factor as cost and astronomical performance.

In the meantime, the NGST Science Team has developed a Design Reference Mission (DRM), representing the core scientific program and a broad range of astronomical observations. It will be used to judge the capabilities of various telescope configurations and to compare aperture benefits and costs with operations costs. Eventually, after extensive scientific and technical debate, the DRM will be refined to be the key tool used in selecting a prime contractor, choosing a design concept and paying contractor incentive award fees.

Reasons for Optimism

Breaking the Hubble cost paradigm has happened. Since the Hubble program began two decades ago, the space industry has evolved considerably. Aerospace companies now offer standard, off-the-shelf commercial products for spacecraft design. These range from relatively low-cost spacecraft electronics to launch vehicles. The industry also has benefited from the revolution in computer technology. With paperless simulation-based design, engineers can run elaborate computer simulations to test design concepts before investing valuable resources in their construction.

The military's investment in space technology also will keep down the observatory's development costs. Its investment in detector technology, for example, has resulted in the development of large infrared array detectors, which are as sensitive as the CCDs used at shorter wavelengths. Furthermore, Lockheed Martin is building the SIRTf spacecraft and has found ways to cut spacecraft bus and integration costs by using radiative cooling. In short, much that seemed impossible just a few years ago is now feasible and affordable.

We can expect the NGST to prosper from these innovations. Instead of building a proprietary system, equipped with custom technology, the next generation observatory will use much of what is already available, bringing down development costs and the time needed to design, build and fly it.

Conclusion

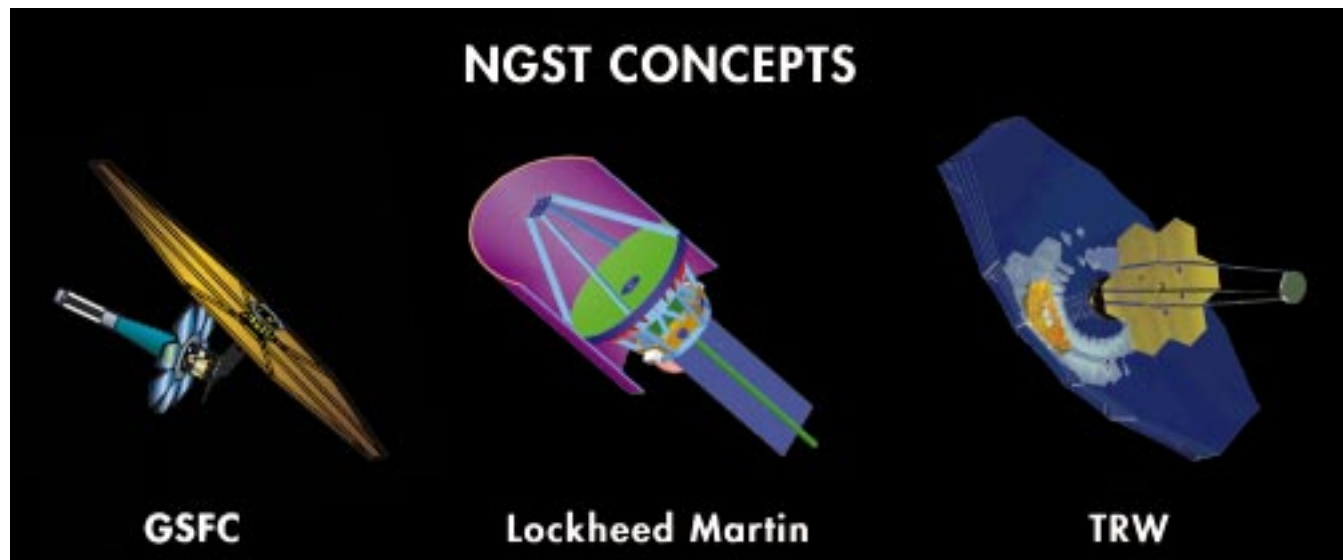
Clearly the NGST is an ambitious program. It demands conceptual breakthroughs, technology refinements and a demonstration of its reliability as evidenced by the NASA and contractor team studies. The competing requirements of “better” and “cheaper” add additional challenges. Although we have not yet reached a point where we can select a specific design approach, it is clear that new concepts and technology will allow us to build NGST for a small fraction of Hubble’s cost. Our path to reach this goal will be made of equal steps — thinking, building, and testing.

What must be stressed is that the observatory’s proposed capabilities will far exceed anything possible from the ground or in space — at least in the foreseeable future. No other mission offers NGST’s combination of large aperture, low temperature and ideal observing environment. The observatory will allow astronomers to study the first protogalaxies, the first star clusters as they make their first generation of stars, and the first supernovae as they release heavy chemical elements into the interstellar gas. With its exceptional sensitivity and wide fields of view, it will let scientists study a range of topics, everything from interstellar chemistry to brown dwarf stars to potential planets around nearby stars.

What we might learn by flying a Next Generation Space Telescope capable of observing the early universe and objects relatively closer to home is incalculable. Though we can plan, we cannot definitely predict the outcome. History has shown that many of the world’s most profound discoveries happen by accident. Our objective now is to prepare for the next generation of discovery, to develop key technologies and fine tune the science requirements. These studies represent a start in the process, a process that is vital if we want the unprecedented era of astronomical discovery begun in the 20th century to continue well into the 21st.

Next Generation Space Telescope **FAST FACTS**

“Visiting a time when galaxies were young...” — HST & Beyond



SCIENCE OBJECTIVES

- Study the birth of the first galaxies
- Determine the shape and fate of the universe
- Study formation of stars and planets
- Observe the chemical evolution of the universe
- Probe the nature of dark matter

TECHNOLOGY HIGHLIGHTS

- Precision deployable and inflatable structures
- Large, low areal density cold active optics
- Simulation based design
- Passive cooling
- Autonomous operations and onboard scheduling

NGST MISSION PROFILE

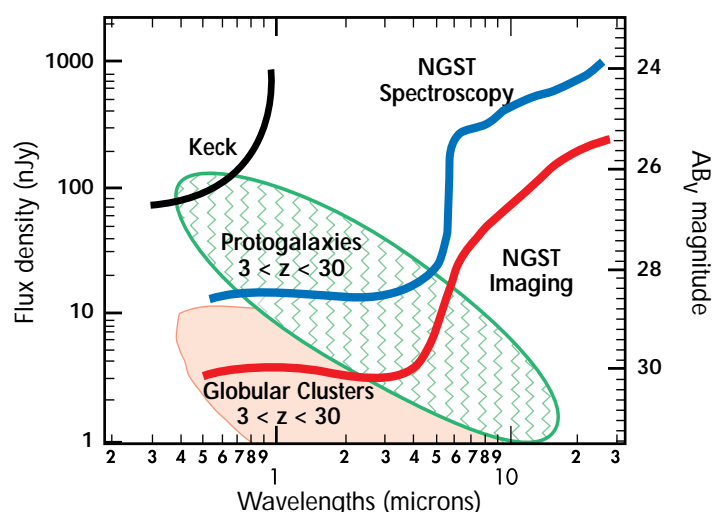
Parameter	Requirement	Goal
Wavelength range	1–5 μm	0.5–30 μm
Aperture diameter	>4 m	>8 m
Angular resolution	Diffraction-limited at 2 μm	Diffraction-limited at 0.5 μm
Spectral resolution	100–1000	100–3000
Optics temperature	<60K	30K
Field of view	4' X 4' at 1–5 μm	Add 2' x 2' coverage 5–30 μm
Sensitivity	Zodiacal background limited at 1 AU orbit	Cosmic infrared background limited
Instantaneous sky coverage	100% available	
Lifetime	5 years	10 years
Orbit	L2 or 1 AU drift	1 X 3 AU

NGST Web Site: <http://ngst.gsfc.nasa.gov/>

CORE SCIENCE PROGRAMS

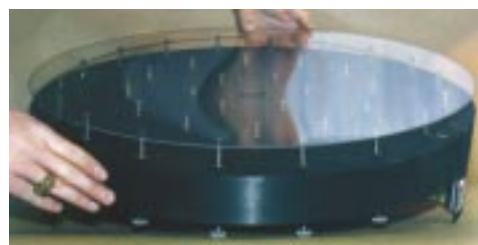
Target Class	Study Objective	Target AB Magnitudes
Deep fields	One deep field (down to AB magnitude 32) and 100 deep less (AB 30) flanking fields will be observed in broad-band filters	30–32
Universe at redshifts $z > 2$	Primeval spheroids, birth and evolution of disks, the origin of heavy elements, birth and evolution of AGN	29 (near-IR) 26 (thermal-IR)
Supernovae study	Improve our knowledge of the geometry of the universe and study the material universe before the birth of galaxies	31
Stellar populations in the nearby universe	Color magnitude to the horizontal branch luminosity both in the optical and in the near	30.5–32
Cosmic distances	Studies, based on gravitational lensing and gravitational time delays, determine dark-matter distribution	27
Kuiper Belt object searches	Statistically meaningful study of their properties as well as of the distribution in space	30 (near-IR) 25 (thermal-IR)
Individual object classes	Variety of studies in both imaging and spectroscopy that can take advantage of the NGST performance, e.g., star formation and the late stages of stellar evolution	

PROJECTED SENSITIVITY

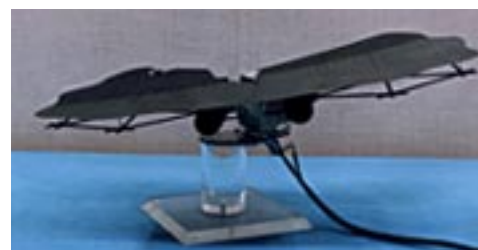


Sensitivity of an 8 m diameter NGST compared with various astronomical phenomena in the early universe. The NGST curves show the signal-to-noise=10 response in 10,000 seconds for wide-band imaging modes and low resolution spectroscopy ($R \sim 100$).

HARDWARE DEVELOPMENT



Prototype active membrane mirror ($d = 0.5$ m, thickness = 2 mm) developed by the University of Arizona.



Precision deployable structure model developed by TRW.

PROPOSED TIMETABLE

Tasks \ Date	FY 1997	FY 1998	FY 1999	FY2000	FY 2001	FY2002	FY 2003	FY2004	FY 2005	FY2006	FY 2007	FY 2008
Project flow	Pre-Phase A		Phase A		Phase B			Phase C/D				Phase E
	Industry Technology											
	GSFC Led Technology Stretch Studies											
Technology challenges	▲	▲	▲	▲	▲	▲						
Project milestones				▲ PNAR	NAR	▲ PDR ▲	CDR ▲				LAUNCH	▲
Technology readiness points			Detectors	Telescope configuration	Inflatables	Orbit selection						